1.0 INTRODUCTION

This report presents the Feasibility Study (FS) for the Portland Harbor Superfund Site (Site) in Portland, Oregon (**Figure 1-1**). The Site was evaluated and proposed for inclusion on the National Priorities List (NPL) pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), 42 United States Code (U.S.C.) §9605, by the U.S. Environmental Protection Agency (EPA) and formally listed as a Superfund Site in December 2000. EPA is the lead agency for this Site and Oregon Department of Environmental Quality (DEQ) is the support agency.

The supporting information used to develop this FS was collected and compiled by the Lower Willamette Group (LWG) and other parties since the inception of the Portland Harbor Remedial Investigation (RI)/FS) in 2001.[1] The LWG prepared a draft FS in 2012 for the Site pursuant to an EPA Administrative Order on Consent for the Portland Harbor RI/FS (AOC; USEPA 2001, 2003, 2006). Oversight of LWG's FS was provided by EPA with support from DEQ. EPA modified the LWG's 2012 FS and finalized the document pursuant to a mutual agreement dated February 4, 2016. EPA has entered into a Memorandum of Understanding (MOU) with DEQ, six federally recognized tribes, two other federal agencies, and one other state agency,[2] who have all participated in providing support in the development of this document.

The RI report (LWG as modified by USEPA 2016) has been completed and characterized the Site sufficiently to define the nature and extent of the source material and the Site-related contaminants. Baseline ecological and human health risk assessments (Windward Environmental, LLC [Windward] 2013; Kennedy/Jenks Consultants [Kennedy/Jenks] 2013) have also been completed. The site characterization and baseline risk assessments are sufficient to complete the FS for the Site.[3]

This FS focuses on approximately ten miles of the lower Willamette River from River Mile (RM) 1.9 (at the upriver end of the Port of Portland's Terminal 5) to RM 11.8 (near the Broadway Bridge). The terms Site, harbor-wide, and Site-wide used in this FS generally refer to the sediments, riverbanks, pore water, and surface water within this reach of the lower Willamette River, not the upland portions of the Site.

This FS is consistent with CERCLA, as amended (42 U.S.C. 9601 et seq.), and its regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] Part 300), commonly referred to as the National

[1] Some of the data used in the FS was collected prior to the listing of the Site.
[2] Government parties that signed the MOU include: the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Grand Ronde Community of Oregon, the Confederated Tribes of Siletz Indians, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, the National Oceanic and Atmospheric Administration, the U.S. Department of the Interior, and the Oregon Department of Fish and Wildlife.
[3] Although this section identifies many specific sources of contamination, neither this section nor this report generally is intended as an exhaustive list of current or historical sources of contamination.

Contingency Plan (NCP) and was prepared in accordance with EPA guidance. Guidance documents used in preparing this FS include:

- *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988)
- *Clarification of the Role of Applicable or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA* (USEPA 1997a)
- *Rules of Thumb for Superfund Remedy Selection* (USEPA 1997b)
- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (USEPA 2002)
- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005)
- *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA 2000)
- *Technical Resource Document on Monitored Natural Recovery* (USEPA 2014)

1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of the FS is to identify, develop, screen, and evaluate a range of remedial alternatives to reduce risks from contaminated media to acceptable levels and to provide the regulatory agencies with sufficient information to select a remedy that meets the requirements established in the NCP. This FS report is comprised of four sections as described below.

- Section 1 – Introduction: Provides a summary of the Site RI, including Site description, Site history, nature and extent of contamination, contaminant fate and transport, and baseline human health and ecological risks.
- Section 2 - Identification and Screening of Technologies: Presents remedial action objectives (RAOs), preliminary remediation goals (PRGs) for addressing human health and ecological risks posed by contaminants in sediment and tissue, general response actions (GRAs) for each medium of interest, identifies areas of media to which general response actions might be applied, identifies and screens remedial technologies and process options, and identifies and evaluates technology process options to select a representative process for each technology type retained for further consideration.

- Section 3 - Development and Screening of Alternatives: Presents a range of remedial alternatives developed by combining the feasible technologies and process options. The alternatives are then refined and screened to reduce the number of alternatives that will be analyzed in further detail. This screening aids in streamlining the FS process while ensuring that the most promising alternatives are being considered.

- Section 4 - Detailed Analysis of Alternatives: Provides the detailed analysis of each alternative with respect to the following seven NCP criteria: 1) overall protection of human health and the environment, 2) compliance with applicable or relevant and appropriate requirements (ARARs), 3) long-term effectiveness and permanence, 4) reduction of toxicity, mobility, or volume through treatment, 5) short-term effectiveness, 6) implementability, and 7) cost. In addition to the detailed analysis, a comparative analysis of remedial action alternatives is also presented in this section. EPA recognizes that this site affects many stakeholders, including communities with environmental justice concerns who live along the river or who live elsewhere but also use the river and considers impacts to these communities in the evaluation of remedial alternatives.

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 miles north to its confluence with the Columbia River, and is one of 14 American Heritage Rivers in the country. It is the 19th largest river in the United States by drainage, and drains 11.7 percent of the State of Oregon. As Oregon's major port and population center, the lower Willamette River sees a great variety of uses including shipping, industrial, fishing, recreational, natural resource, and other uses. The lower reach of the Willamette River from RM 0 to approximately RM 26.5 is a wide, shallow, slow moving segment that is tidally influenced with tidal reversals occurring during low flow periods as far upstream as Ross Island at RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the lower Willamette River system. The lower reach has been extensively dredged to maintain a 40-foot deep navigation channel from RM 0 to RM 11.7.

The Site is located within the lower reach of the lower Willamette River in Portland, Oregon known as Portland Harbor (**Figure 1-1**). The Site extends approximately from RM 1.9 to 11.8. While the harbor area is extensively industrialized, it occurs within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the lower Willamette River in the harbor includes marine terminals, manufacturing, and other commercial operations, as well as public facilities, parks, and open spaces. **Figures 1.2-1a** through **1.2-1d** illustrate land use zoning within the lower Willamette River as well as waterfront land ownership. The State of Oregon owns certain submerged and submersible lands underlying navigable and tidally influenced waters. The ownership of submerged and submersible lands is complicated and has changed over time. **Figure 1.2-2** presents the current submerged land ownership.

Today the Willamette River is noticeably different from the river prior to industrial development that commenced in the mid to late 18th century. Historically, the Willamette River was wider with more sand bars and shoals and flow volumes were subject to greater seasonal fluctuation. The main river now has been redirected and channelized, several lakes and wetlands in the lower floodplain have been filled and agricultural lands converted to urban or industrial areas. The end result is a river that is deeper and narrower than it was historically with higher banks that prevent the river from expanding during high-flow events. The width of the Willamette River from the Broadway Bridge (RM 11.6) to the mouth (RM 0) currently varies from 600 to 1,900 feet. Further, the installation of a series of dams moderate fluctuations of flow in the lower Willamette River.

Little, if any, original shoreline or river bottom exists that has not been modified by or resulted from the above actions. Much of the shoreline has been raised, filled, stabilized, and/or engineered and contains overwater piers and berths, port terminals and slips, stormwater and industrial wastewater outfalls and combined sewer overflows (CSOs), and other engineered features. Constructed structures, such as wharfs, piers, floating docks, and pilings, are especially common in the Site where urbanization and industrialization are most prevalent. These structures are built largely to accommodate or support shipping traffic within the river and to stabilize the riverbanks for urban or commercial/industrial development. Constructed structures are clearly visible in the aerial photos provided in **Figures 1.2-3a** through **1.2-3n.**

Armoring to stabilize the riverbanks covers approximately half of the harbor shoreline is integral to the operation of activities that characterize the Site. Riprap is the most common bank-stabilization measure. However, bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to stabilize banks and limit periodic flooding as most of the original wetlands bordering the Willamette in the Portland Harbor area have been filled. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate and beaches have formed along some modified shorelines.

A federal navigation channel, maintained to a depth of -40 feet with an authorized depth of -43 feet, extends from the confluence of the lower Willamette River with the Columbia River to RM 11.7. The lower Willamette River federal navigation project was first authorized in 1878 to deepen and maintain parts of the Columbia River and lower Willamette River with a 20-foot minimum depth. The depth of the navigation channel has been deepened at various intervals since that time; it was increased to 25 feet in 1899, 30 feet in 1912, 35 feet in 1930, and 40 feet in 1962. Container and other commercial vessels regularly transit the river. Certain parts of the river require periodic maintenance dredging to keep the navigation channel at its maintained depth. In addition, the Port of Portland and other private entities periodically perform maintenance dredging to support access to dock and wharf facilities. Except for the emergency dredging of some shoals, little navigational dredging has been performed since 1997 due to contamination of the river bottom. Dredging activity has greatly altered the physical and ecological environment of the river in the Site. The location of the federally authorized navigation channel and the future maintenance dredge areas are depicted on **Figures 1.2-4a through 1.2-4e**.

Development of the river has resulted in major modifications to the ecological function of the lower Willamette River. However, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that exist within and along the river. The river is also an important rearing site and pathway for migration of anadromous fishes, such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, are active within the lower Willamette River. A detailed description of ecological communities in the Site is presented in the baseline ecological risk assessment (BERA) provided as Appendix G of the RI report.

1.2.2 Site History

Since the late 1800s, the Portland Harbor section of the lower Willamette River has been extensively modified to accommodate a vigorous shipping industry. Modifications include redirection and channelization of the main river, draining seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Historically, the Willamette was wider, had more sand bars and shoals, and fluctuated greatly in volume.

The lower Willamette River and its adjacent upland areas have been used for industrial, commercial, and shipping operations for over a century. Commercial and industrial development in the Site accelerated in the 1920s and again during World War II, which reinvigorated industry following the Great Depression. Before World War II, industrial development primarily included sawmills, manufactured gas production (MGP), bulk fuel terminals, and smaller industrial facilities. During World War II, a considerable number of ships were built at military shipyards located in the Site. Additional industrial operations located along the river in the post-World War II years included wood-treatment, agricultural chemical production, battery processing, ship loading and unloading, ship maintenance, repair and dismantling, chemical manufacturing and distribution, metal recycling, steel mills, smelters, foundries, electrical production, marine shipping and associated operations, rail yards, and rail car manufacturing. Many of these operations continue today. Contaminants associated with these operations were released from various sources and migrated to the lower Willamette River. The long history of industrial and shipping activities in the Site, as well as agricultural, industrial, and municipal activities upstream of the Site, has contributed to chemical contamination of surface water, sediment, and biota in the lower Willamette River.

1.2.2.1 Investigation History

Many environmental investigations by private, state, and federal agencies have been conducted, both in the lower Willamette River and on adjacent upland properties, to characterize the nature and extent of contamination in the river, as well as to identify potential sources of contaminants that could continue to enter the river. Investigations have been conducted in the Site from the 1920s to the present, with most studies being performed from the late 1970s through the present. Nearly 700 documents and data sets were obtained that address conditions in the lower Willamette River. Specific historical and recent studies and data sets were selected for inclusion in the data set used to characterize and evaluate the Site in the RI and FS reports.

Site data were collected by the LWG during four major rounds of field investigations between 2001 and 2010 to complete the RI. The investigations were often timed around varying river height stages, river flows, and storm events. The field investigations first began in 2001 in the Initial Study Area (ISA) as defined by the AOC, Statement of Work (SOW), and Programmatic Work Plan as RM 3 to RM 9. As the studies commenced, the study area was expanded from RM 1.9 to RM 11.8, as well as a portion of the Multnomah Channel. Studies conducted by the LWG also included areas downriver of the Site to the confluence with the Columbia River at RM 0 and upriver to RM 28.4. Surface and subsurface sediment samples, sediment trap samples, riverbank sediment and soil samples, surface water samples, stormwater and stormwater solids samples, groundwater samples, transition zone water (TZW) samples, and biota/tissue samples were collected and analyzed during the various investigations conducted.

1.2.2.2 Upland Source Control Measures

Identifying current sources of contamination to the Site and eliminating or minimizing these pathways, where possible, is critical for maximizing remedy effectiveness by minimizing the potential for recontamination of the sediment, surface water, and biota and overall long-term protectiveness after cleanup. In February 2001, DEQ, EPA, and other governmental parties signed an MOU agreeing that DEQ, using state cleanup authority, has lead technical and legal responsibility for identifying and controlling upland sources of contamination that may impact the river. Currently, DEQ is investigating or directing source control work at over 90 upland sites in the Site and evaluating investigation and remediation information at more than 80 other upland sites in the vicinity of the Site (DEQ 2014). Additionally, DEQ is working with the City of Portland under an Intergovernmental Agreement to identify and control upland sources draining to the Site through 39 city outfalls, and with the Oregon Department of Transportation controlling highway and bridge runoff to the Site (City of Portland 2012).

The City prepared a Combined Sewer Outfall (CSO) Management Plan (City of Portland 2005) with recommendations to address wet weather overflow discharges, including implementation of storage and treatment facilities along the Willamette River ("Big Pipe project") to control the CSO discharges. The primary means for increasing the storage capacity was through construction of the West Side Tunnel (completed in 2006) and the East Side Tunnel (completed in 2011).

The cleanup of known or potentially contaminated upland sites is tracked in DEQ's Environmental Cleanup Site Information (ECSI) database, which is available online at http://www.deq.state.or.us/lq/ECSI/ecsi.htm, and source control efforts are summarized in DEQ's Portland Harbor Upland Source Control Milestone and Summary Report (http://www.deq.state.or.us/lq/cu/nwr/PortlandHarbor/jointsource.htm).

Figures 1.2-5a through **1.2-5e** graphically display the status of DEQ's source control evaluations as of 2014 for various sites along the Site by potential release/migration pathways to the river. An important overall assumption of the FS is that upland sources in the Site will be sufficiently controlled to achieve remedial action objectives using the DEQ process.

1.2.2.3 Early Action Sites

Within the Site, separate orders have been executed by EPA with various parties for five specific sites. These sites are:

1. Terminal 4 – conducted by the Port of Portland
2. Gasco – conducted by NW Natural
3. Gasco and Siltronic – conducted by NW Natural and Siltronic
4. Arkema – conducted by Arkema
5. RM 11 E – conducted by Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland

These projects are currently in various stages of completion as described below.

- **Terminal 4 –** The Port of Portland has been implementing a removal action at Terminal 4. A Phase I Abatement Measure was completed in 2008. Remediation consisted of dredging 12,819 cubic yards of contaminated sediment and placing it in an off-site disposal facility, isolating contaminated sediment with an organoclay-sand mix cap in the back of Slip 3, and stabilizing the bank along Wheeler Bay.

- **Gasco –** A removal action was conducted at the Gasco site between August and October 2005. Approximately 15,300 cubic yards of a tar-like material and tar-like contaminated sediment were removed by dredging the riverbank and nearshore area adjacent to the Gasco facility and disposed of off-site. After the removal action, an organoclay mat was placed along an upper-elevation band of the shoreline dredge cut. This mat was secured in place with a sand cap and quarry spalls (crushed rock). A one foot thick sand cap and 0.5 foot of erosion protection gravel was placed over the remainder of the removal area (0.4 acres). Approximately 0.5 foot of a "fringe cap" of sand material was placed over 2.3 acres of the area surrounding the removal area.

- **Gasco and Siltronic –** NW Natural and Siltronic are conducting site characterization and design evaluations for the area adjacent to their two facilities. Under the order, NW Natural and Siltronic have agreed to perform further characterization, studies, analysis and preliminary design for the final remedy at the Gasco Sediment site. The studies and other work under the SOW will be incorporated into the Portland Harbor RI/FS for the remedy decision for the Portland Harbor Superfund Site. The design of the final remedy selected will be performed under the order. No cleanup actions have been taken to date.

- **Arkema –** Under an AOC with EPA, Arkema conducted additional site characterization and preliminary design evaluations for a planned Removal Action. No cleanup actions have been taken to date.

- **River Mile 11 East -** A group of Respondents, collectively known as the RM 11E Group (includes Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland), entered into an AOC with EPA to perform supplemental Portland Harbor RI/FS work in support of preliminary design activities. No cleanup actions have been taken to date.

In addition, a sediment removal action of the near-shore adjacent to the BP Arco Bulk Terminal in 2007-08 under DEQ oversight resulted in the removal and off-site disposal of 12,300 cubic yards of petroleum-contaminated soil and sediment. Removed material was replaced with clean fill and a new steel sheet-pile seawall was installed along the entire riverbank of the BP Arco Bulk Terminal property.

1.2.3 Nature and Extent of Contamination

Due to the large number (over 200) of contaminants detected at the Site in various media, the nature and extent of contamination focuses on specific contaminants or groups of contaminants selected by evaluating several criteria discussed in Section 5.1 of the RI report.

As discussed in detail in Section 5 of the RI report, 14 contaminants were identified based on frequency of detection, ease of cross media comparisons, co-location with other contaminants, widespread sources, and similar chemical structures and properties. Information regarding an additional 18 contaminants is provided in Appendix D of the RI report. The concentrations of these contaminants in sediment and surface water are summarized in the following sections. As discussed in Section 5.1 of the RI report, additional contaminants beyond the indicator contaminants presented in the RI report (and summarized in this section) are present at the Site at concentrations that may pose unacceptable risk to human health and the environment. Section 2.2.1 of this FS identifies the contaminants of concern (COCs) selected for the Site and discusses the process for selecting the COCs. In addition, the data and information used to determine nature and extent of groundwater and riverbank contamination was collected by individual parties under DEQ oversight, but was not discussed in the RI report.

1.2.3.1 Sources

Historical and current locations of various industrial facilities identified along the lower Willamette River are provided by industrial sector in **Figures 1.2-5a** through **1.2-5j**. The approximate location of facilities is shown on the maps; however, the actual extent of historical and current facilities/operations is not shown. Detailed information regarding historic and current sources of contamination in the lower Willamette River is provided in Section 4 of the RI report.

Contaminants released during industrial operations and/or other activities to the air, soil, groundwater, surface water, and/or impervious surfaces can potentially migrate to the lower Willamette River via the following pathways: direct discharge, overland transport, groundwater, riverbank erosion, atmospheric deposition, overwater activities, and upstream watershed.

One key migration pathway for contaminants from these various industries to the river was through direct discharge via numerous public and private outfalls, including storm drains and CSOs, which are located along both shores of the lower Willamette River in the metropolitan area. In the early 1900s, rivers in the United States were generally used as open sewers, which was also true for the Willamette (Carter 2006). The process water from a variety of industries, including slaughterhouses, chemical plants, electroplaters, paper mills, and food processors, was discharged directly into the river. In the 1950s, municipal conveyance systems included interceptors and associated facilities were installed to reduce the volume of untreated sewage discharging to the Willamette from the City of Portland and regulatory actions in the 1960s and 1970s, such as the Clean Water Act, gradually reduced the direct discharge of waste to the Willamette River.

Direct discharges and releases from upland or overwater activities at the Site likely contributed to the majority of the observed contaminant distribution in sediments. The majority of current contaminant pathways to the river (soil erosion, groundwater, and stormwater) from upland sources are a result of historical operational practices, spills, and other releases.

In addition, stormwater and nonpoint discharges within the Willamette River Basin are potential sources of contamination to the sediment, surface water, and biota at the Site. Contaminants in discharges and runoff from diverse land uses in the basin eventually enter the river upstream of the Site. Contaminant loading from sediment transport and water from upstream areas throughout the last century also contributed to the conditions currently observed at the Site.

1.2.3.2 Sediment

Sediment samples were collected from the Site and the lower Willamette River. Much of the sampling was conducted by the LWG under the terms of the AOC and consistent with EPA approved work plans. Sample locations were biased toward areas of known or suspected contamination. Additional sampling was conducted both upstream and downstream of the Site. Summary statistics of surface and subsurface sediment concentrations for the indicator contaminants are provided in **Table 1.2-1**. Generally, concentrations of the contaminants were greater in subsurface sediment samples relative to concentrations in surface samples, confirming that historical inputs were greater than current inputs. However, there are noted areas at the Site where surface concentrations are greater than subsurface concentrations likely reflecting more recent releases and/or disturbance of bedded sediments.

PCBs

With few exceptions, the highest polychlorinated biphenyl (PCB) concentrations in surface sediment are present in nearshore areas outside the navigation channel and proximal to known or suspected sources (**Figure 1.2-6a**). Similar spatial and concentration trends are observed for subsurface sediments (**Figure 1.2-6b**). Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical. Overall, surface sediment PCB concentrations at the Site are greater than those in the upriver (upstream of Ross Island at RM 16) and downstream (main stem of the lower Willamette River downstream of RM 1.9 and Multnomah Channel) reaches.

Dioxins/Furans

Total polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) were detected at several locations along the eastern and western nearshore zones and in Swan Island Lagoon (**Figure 1.2-7a**). Limited surface PCDD/F data are available; thus, spatial resolution is somewhat limited, especially in the navigation channel. Total PCDD/F concentrations in the subsurface are generally greater than that observed in surface sediments (**Figure 1.2-7b**). The higher concentrations generally observed in subsurface sediment relative to concentrations in surface sediment are indicative primarily of historical input of these contaminants to the Site.

DDx

The highest reported DDx concentrations in surface sediments are present in localized areas in the western nearshore zones between RMs 6.3 and 7.5 (**Figure 1.2-8a**). DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical (**Figure 1.2-8b**). The concentrations of DDx in surface sediments are greater at the Site than those in the upriver, downtown, Multnomah Channel, and downstream reaches.

Total PAHs

The highest reported concentrations of total polycyclic aromatic hydrocarbons (PAHs) in surface sediments generally occur in the western nearshore zone downstream of RM 6.8, and on the east side at approximately RM 4.5 (**Figure 1.2-9a**). Total PAH concentrations are generally higher in subsurface sediments at the Site as a whole, pointing to higher historical inputs to the Site (**Figure 1.2-9b**). At the Site, total PAHs in sediment are generally dominated by high molecular weight PAHs (HPAHs). Surface sediments from the western nearshore zone appeared to exhibit higher proportions of low molecular weight PAHs (LPAHs) than sediments from the eastern nearshore zone and the navigation channel, but follow the general trend of HPAH dominance. Subsurface sediments generally exhibit similar PAH profiles to those in the surface sediments.

Bis(2-ethylhexyl) phthalate

The highest reported concentrations of bis(2-ethylhexyl)phthalate (BEHP) were observed in samples collected in surface and subsurface sediment from the eastern nearshore in Swan Island Lagoon, between RM 3.8 and 4.1, and in the International Terminals Slip (**Figures 1.2-10a and 1.2-10b)**. BEHP concentrations are generally greater in surface than in subsurface sediments indicating more recent inputs to the Site.

Total Chlordanes

The highest reported concentrations of total chlordanes were observed along the western nearshore zone between approximately RM 7 and 9 (**Figure 1.2-11a**). Total chlordane concentrations are generally higher in subsurface sediments at the Site, pointing to higher historical inputs to the Site (**Figure 1.2-11b**).

Aldrin and Dieldrin

Aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin readily undergoes biotic and abiotic transformation to dieldrin. The highest reported concentrations of aldrin were observed in the western nearshore zone from RM 6.8 to RM 7 and from RM 8.6 to RM 8.8 (**Figures 1.2-12a)**. The highest reported surface concentrations of dieldrin were observed in Swan Island Lagoon and in the western nearshore zone from RM 8 to 9 (**Figure 1.2-13a**). Aldrin and dieldrin concentrations are higher in subsurface sediments than surface sediments at the Site (**Figures 1.2-12b and 1.2-13b**), indicating higher historical inputs of these pesticides to the Site.

Metals

The highest reported arsenic concentrations were reported in several locations in the eastern nearshore at RM 2.3, RM 5.6, RM 7.2, near the mouth of Swan Island Lagoon, and in the western nearshore area at RM 6.8, RM 8.6, and RM 10.2 (**Figure 1.2-14a**). Arsenic concentrations are generally greater in the surface sediments than in subsurface sediments at the Site (**Figure 1.2-14b**). This indicates recent arsenic inputs to the Site.

The highest reported chromium concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4.4, RM 5.6-5.9, and in Swan Island Lagoon, and in the western nearshore zone at RM 6-6.1, RM 6.8-6.9, and RM 8.8-9.2 (**Figure 1.2-15a**). Chromium concentrations are generally greater in the surface sediments than in subsurface sediments at the Site (**Figure 1.2-15b**). This indicates recent chromium inputs to the Site.

The highest surface and subsurface copper concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4, RM 5.5-6.1, RM 11.1-11.3, and Swan Island Lagoon, and in the western nearshore zone from RM 4.3 through 10.4 (**Figure 1.2-16a**).

Copper concentrations are generally similar in surface and subsurface sediments at the Site (**Figure 1.2-16b**).

The highest surface sediment zinc concentrations were found in the eastern nearshore zone at RM 4-4.6, RM 5.6, and RM 6.7, and the western nearshore zone between RM 8 and 9.2 (**Figure 1.2-17a**). The highest subsurface concentrations of zinc were found in the western nearshore zone at RM 9-9.2 and in Swan Island Lagoon (**Figure 1.2-17b**). Zinc concentrations are generally similar in the surface and subsurface sediments at the Site.

Tributyltin Ion

The highest concentrations of tributyltin were reported in surface sediment near the eastern nearshore zone at RM 3.7, RM 7.5, and in Swan Island Lagoon (**Figure 1.2-18a**). The highest subsurface concentrations of tributyltin are found in the eastern nearshore zone between RM 7 and RM 8, and in Swan Island Lagoon (**Figure 1.2-18b**). Concentrations are generally higher in subsurface than surface sediments at the Site, indicating primarily historical inputs to the Site.

1.2.3.3 Surface Water

Concentrations of contaminants in surface water samples varied both spatially and with river flow. Surface water sample locations with the highest reported contaminant concentrations are as follows:

River Mile	River Location	Sample ID	Contaminants
Multnomah Channel	Transect	W027	PCDD/Fs, aldrin, copper
2	East	W001	PCBs, DDx
	West	W002	chlordanes
	Transect	W025	PCBs, BEHP, aldrin
3	International Slip	W004	PCBs
	East	W028	PCBs
4	West	W029	BEHP, chlordanes
5	East	W030	PCBs, DDx, chlordanes
6	East	W013, W014, W032	PCBs, PCDD/Fs
	West	W015, W031	PCBS, PCDD/Fs, DDx, PAHs, chlordanes, aldrin, dieldrin, copper
	Transect	W011	PCDD/Fs, BEHP, aldrin
7	West	W016, W033	PCBs, PCDD/Fs, DDx
8	West	W019, W036	PCBs, PAHs, BEHP
9	West	W022, W037	DDx, zinc
11	Transect	W023	PCDD/Fs, chlordanes, copper
16	Transect	W024	BEHP, copper

RM 7E, RM 8E, RM 9E, and RM 10 were not sampled.

Concentrations of contaminants in surface water at the Site are generally higher than those entering the upstream limit of the Site (W024 at RM 16) under all flow conditions. The highest contaminant concentrations in surface water at the Site were found near known sources. Concentrations of total PCBs, dioxins/furans, DDx, BEHP, chlordanes, and aldrin in surface water are greater at the downstream end of the Site [RM 2 (W001, W002, W025) and in the Multnomah Channel (W027)] than concentrations entering the Site, which indicates that contamination from the Site is being transported downstream to the Columbia River.

1.2.3.4 Groundwater

Figure 1.2-19 and **Figure 1.2-20** show the nature and extent of known contaminated groundwater plumes currently or potentially discharging to the river. Cleanup of contaminated groundwater is being addressed and managed by DEQ under an MOU with EPA (see 1.2.2.2, above). However, in-water actions may need to be considered under this response to address residual impacts from these groundwater plumes. The following provides a discussion of the groundwater plumes presented in **Figures 1.2-19** and **1.2-20.** Additional information on these areas is available in DEQ's ECSI database.

<u>East Side of Willamette River</u>

RM 2
<u>Evraz Oregon Steel Mill</u> (ESCI Site ID 141) – Contaminants are manganese and arsenic.

RM 3.5
<u>Time Oil</u> (ECSI Site ID 170) – Contaminants are pentachlorophenol, arsenic, and gasoline- and diesel-range hydrocarbons.

<u>Premier Edible Oil</u> (ECSI Site ID 2013) – Contaminants are total petroleum hydrocarbon (TPH) (diesel-range hydrocarbons), manganese, and arsenic.

<u>Schnitzer Steel Industries</u> (ECSI Site ID 2355) – Contaminants include cis-1,2-dichloroethene (cis-1,2-DCE), tetrachloroethene (PCE), and trichloroethene (TCE).

<u>NW Pipe</u> (ECSI Site ID 138) – Contaminants include PCE, TCE, and vinyl chloride.

RM 4.5
<u>Terminal 4 Slip 3</u> (ECSI Site ID 272) – Contaminants include TPH (diesel-range hydrocarbons).

RM 6
<u>McCormick & Baxter Creosote Co.</u> (ECSI Site ID 74) – Contaminants include pentachlorophenol, PAHs, arsenic, chromium, copper, and zinc.

<u>Willamette Cove</u> – Contaminants include PCBs (Rodenburg et al. 2015).

RM 11
Tarr Oil (ECSI Site ID 1139) –Contaminants include cis-1,2-DCE, PCE, TCE, and vinyl chloride.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – Contaminants include light non-aqueous phase liquids (LNAPL), diesel-range hydrocarbons, residual-range hydrocarbons, and gasoline-range hydrocarbons.

RM 5
BP Arco Bulk Terminal (ECSI Site ID 1528) – Contaminants include TPH (gasoline-range and diesel-range hydrocarbons) and the plume extends under the adjacent downstream property.

Exxon Mobil Bulk Terminal (ECSI Site ID 137) – Contaminants include gasoline- and diesel-range hydrocarbons.

RM 5.5
Foss Maritime/Brix Marine (ECSI Site ID 2364) – Contaminants include gasoline- and diesel-range hydrocarbons.

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Contaminants detected in groundwater include PAHs, semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs) (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]), cyanide, sulfide, sulfate and carbon disulfide, ammonia, and metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc). Gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons and total petroleum hydrocarbon fractions are being added to the groundwater monitoring program.

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – Contaminants include petroleum-related and chlorinated VOCs (benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,1-dichloroethene, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride), PAHs, gasoline-range, diesel-range, and residual-range hydrocarbons, cyanide, metals (arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, thallium, vanadium, and zinc), 2,4,5-trichlorophenoxyacetic acid (2,4,5-TP), and 2-(2,4-dichlorophenoxy)propionic acid (2,4-DP).

RM 7
Rhone Poulenc (ECSI Site ID 155) – Known releases of organochlorine insecticides and herbicides, including pentachlorophenol (PCP), 2,4-DP, Bromoxynil, 4(2,4-dichloropenoxy)butyric acid (2,4-DB), 2-methyl-4-chlorophenoxyacetic (MCPA),

methylchlorophenoxypropionic acid (MCPP), 4-(4-chloro-2-methylphenoxy)butanoic acid (MCPB), 2,4,5-trichlorophenoxyacetic acid [2,4,5-T], 2,4-dichlorophenoxyacetic acid (2,4-D), DDT, Endrin, Heptachlor, sodium chlorate, sodium arsenate, 2,4,5-TP, aldrin, dieldrin, chlordanes, and 2,4-DP have occurred at the site.

Contaminants migrating in groundwater include VOCs, and herbicides. Contaminants infiltrating City Outfall 22B include: SVOCs (2,4,6-trichlorophenol, 2,4-dichlorophenol, 2-methylphenol, pentachlorophenol, and naphthalene), insecticides (aldrin, alpha-chlordane, dieldrin, gamma-chlordane, heptachlor epoxide, hexachlorobenzene, DDD, DDE, and DDT), dioxin/furans (2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD]) and metals (aluminum, boron, molybdenum, thallium, arsenic, barium, iron, manganese) (DEQ 2013).

Kinder Morgan Pump Station (ECSI Site ID 2104) – Contaminants include TPH.

Arkema (ECSI Site ID 398) – Contaminants detected in groundwater at the site include, but are not limited to, DDT and its metabolites DDD and DDE (DDx) and VOCs (chlorobenzene, chloroform, PCE, TCE and benzene), perchlorate and hexavalent chromium. A chloride groundwater plume associated with the former salt piles is also present at the site.

RM 8

Kinder Morgan Willbridge Bulk Terminal (ECSI Site ID 160) – Contaminants include gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and arsenic.

Chevron and Unocal Willbridge Bulk Terminal (ECSI Site IDs 25 and 177) – Contaminants include gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and metals (arsenic and manganese).

Chevron Asphalt Plant (ECSI Site ID 1281) – Contaminants include TPH (diesel-range and gasoline-range hydrocarbons), arsenic, BTEX and naphthalene.

RM 9

Gunderson (ECSI Site ID 1155) – Contaminants include 1,1-DCE, 1,1,1-trichloroethane [1,1,1-TCA], PCE, TCE, vinyl chloride, and PAHs.

Christensen Oil (ECSI Site ID 2426) – Contaminants include TPH (Stoddard solvent).

Univar (ECSI Site ID 330) – Contaminants include 1,1-dichloroethane (DCA), 1,1-DCE, cis-1,2-DCE, methylene chloride, PCE, toluene, 1,1,1-TCA, TCE, vinyl chloride, and xylenes.

Galvanizers Inc. (ECSI Site ID 1196) – Contaminants include zinc.

RM 10
Sulzer Pump (ECSI Site ID 1235) – Contaminants include TPH, PAH, and VOCs.

RM 11.5
Centennial Mills (ECSI Site ID 5136) – Contaminants include TPH (diesel-range hydrocarbons).

1.2.3.5 Riverbanks

Riverbanks are a source of contamination to the Willamette River. This section provides a discussion of the known contaminated banks that are evaluated as part of this FS. These areas are contaminated by a variety of COCs that can enter the river through erosion or anthropogenic activities and will then reside in the sediment bed, water column, or enter into the aquatic food chain. Characterization and evaluation of contaminated banks is being managed by DEQ under an MOU with EPA. River bank remediation has already occurred at several locations in the Site, managed by DEQ under an MOU with EPA (see Section 1.2.2.2 above).

Since riverbank contaminations is directly linked to the sediment bed and receptors through proximity and source and migration pathways, the known areas of contamination are included here and elsewhere in the FS. Including these areas supports the evaluation of and selection of alternatives in case it is determined that river bank contamination is best suited for remediation in conjunction with in-river activities. Other riverbanks may be included in the remedial action in the river, if contamination is found during remediation of the river sediment. Information on these river banks is available in DEQ's ECSI database and in the FS riverbank data compilation found in Appendix A.

East Side of Willamette River

RM 2
Evraz Oregon Steel Mill (ECSI Site ID 141) – Contaminants present in the riverbank includes PCBs and metals (arsenic, cadmium, chromium, copper, lead, manganese, and zinc).

RM 3.5
Schnitzer Steel Industries (ECSI Site ID 2355) – Soils samples collected under the docks along the south shore of the International Slip have been found to be contaminated with PCBs and dioxins.

Premier Edible Oil (ECSI Site ID 2013) – Contaminants may include mercury, cobalt, antimony, barium, PAHs, zinc, copper, manganese, arsenic, carbazole, dibenzofuran, methylnaphthalene, petroleum hydrocarbons, BTEX, chlorinated solvents, and bis(2-ethylhexyl)phthalate.

RM 5.5
MarCom South (ECSI Site ID 2350) – Further investigation of the nature and extent of contamination in the riverbank was conducted in 2012. Contaminants are PAHs and metals (arsenic, cadmium, chromium, copper, zinc).

RM 7
Willamette Cove (ECSI Site ID 2363) - Riverbank contaminants are PCBs, dioxins/furans, metals (lead, mercury, nickel, and copper), and PAHs.

RM 8.5
Swan Island Shipyard (ECSI Site ID 271) – Recent sampling results indicate that contaminants include metals (arsenic, cadmium, chromium, copper, lead, mercury, and zinc), PAHs, PCBs, and tributyltin.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – Contaminants are petroleum constituents (BTEXs and PAHs) and metals (arsenic and lead).

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Contamination associated with historical MGP waste are known to be located in the riverbank. Contaminants include PAHs, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, cyanide, and metals (zinc).

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – Contamination associated with historical MGP waste is known to be present in the northern portion of the Siltronic riverbank. Riverbank contaminants include PAHs, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbon and cyanide and metals (zinc).

BNSF Railroad Bridge – Contamination associated with pesticide and herbicide releases from Rhone Poulenc and Arkema are known to be present in the riverbank below and adjacent to the BNSF railroad bridge. Riverbank contaminants include dioxin/furans, metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, zinc, insecticides (DDD, DDE, DDT, aldrin, alpha-hexachlorocyclohexane [alpha-BHC], alpha-chlordane, beta-BHC, cis-nonachlor, delta-BHC, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, gamma-BHC, gamma-chlordane heptachlor, heptachlor epoxide, hexachlorobutadiene, methoxychlor, Mirex, oxychlordane, and trans-nonachlor), PCBs, SVOCs (acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzoic acid, benzyl alcohol, bis

(2-ethylhexyl)phthalate, butylbenzylphthalate, chrysene, bibenzo(a,h)anthracene, dimethylphthalate, di-n-butylphthalate, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene). (AMEC 2011).

RM 7
Arkema (ECSI Site ID 398) –Riverbank contaminants include DDT, dioxin/furans, PCBs, and metals (chromium and lead).

GS Roofing (ECSI Site ID 117) – Riverbank contaminants include TPH and metals Arsenic (As), Chromium (Cr), Lead (Pb), Mercury (Hg), Nickle (Ni), and Selenium (Se).

RM 8
Hampton Lumber and Glacier NW (ECSI Site ID 1239) – Riverbank contaminants include steel mill slag fill.

RM 9
Gunderson (ECSI Site ID 1155) – Contaminants include metals (lead, nickel, and zinc), and PCBs.

RM 10
Sulzer Bingham Pumps (ECSI Site ID 1235) – Riverbank contaminants include PCBs and metals Arsenic, (As), Copper (Cu), Lead (Pb), Manganese (Mn) and Zinc (Zn).

1.2.4 Contaminant Fate and Transport

Sediment contamination at the Site is associated with historical and recent sources and practices. Persistent contaminants (particularly PCBs and dioxin/furans) from sediments and surface water bioaccumulate in the food chain and usually result in the greatest risks to humans and wildlife that ingest fish and shellfish.

Internal contaminant fate and transport processes are those processes that affect the fate, transport and redistribution of contaminants at the Site, as opposed to those processes that may affect the fate of contaminants in biota. The major internal fate and transport processes are:

- Erosion from the sediment bed
- Deposition to the sediment bed
- Dissolved flux from the sediment bed (pore water exchange)
- Groundwater advection
- Degradation (for some contaminants)

- Volatilization
- Downstream transport of either particulate-bound or dissolved phase contaminants

These processes interact to create complex patterns of sediment contamination that vary spatially, temporally, and by contaminant. Empirical estimates of contaminant loading associated with internal and external contaminant sources are provided in **Figures 1.2-21** through **1.2-25**. A discussion of the methodology used to derive the contaminant loading is provided in **Appendix D**. External sources include upstream loading, “lateral” external loading such as stormwater runoff, permitted discharges, upland groundwater, atmospheric deposition, direct upland soil and riverbank erosion, uncontaminated groundwater advection through contaminated subsurface sediments, and overwater releases. Internal sources include surface sediment loading to the surface water via sediment and riverbank erosion and sediment pore water exchange, as well as deposition to surface sediment from surface water. **Figures 1.2-26** provides a visual summary of currently known or suspected contaminant source loads within and exiting from the Site for three representative contaminants: total PCBs, benzo(a)pyrene, and DDE.

Elevated contaminant concentrations at the Site are typically associated with areas near likely historical and/or existing sources. Although the highest sediment contaminant concentrations are generally found in nearshore areas, elevated-concentrations are also found in the higher-energy portion of the channel between RM 5 and 7. This may reflect past or current dispersal of material away from nearshore source areas. Throughout the Site, contaminant concentrations are generally higher in subsurface sediments than in surface sediments, indicating both higher historical contaminant inputs and improving sediment quality over time. Localized exceptions to the pattern of higher subsurface sediment concentrations exist in a few areas for some contaminants, likely reflecting more recent releases and/or disturbances of bedded sediments through natural or anthropogenic processes. Also, the depth of subsurface contamination is generally greater in nearshore areas as compared to the navigation channel.

Generally, areas of elevated contaminant concentrations in surface sediment correspond to areas of elevated concentrations in subsurface sediment, particularly in nearshore areas. Areas where only surface or subsurface sediments exhibited elevated contaminant concentrations point to spatially and temporally variable inputs and sources, or to different influences from sediment transport mechanisms. Areas of higher contaminant concentrations are generally distinct from those in surrounding areas of lower concentrations. Within these areas, distinctly higher contaminant concentrations are also noted in sediment traps, and in the particulate portion of the corresponding surface water samples. For example, these patterns are presented for PCBs, PAHs, dioxins/furans and DDx in **Tables 1.2-5 through 1.2-8**.

Most areas of elevated contaminant concentration in sediment are located in nearshore areas. Downstream migration/dispersal of contaminants from these areas is apparent in sediment data patterns. The elevated levels in subsurface sediment indicate historical releases from upland and overwater sources while the lower surface sediment concentrations suggest the deposition and mixing of cleaner upriver sediments in contaminated areas.

Based on results of surface water data collected during the RI, resuspension and/or dissolved phase flux from the sediment bed and to some degree riverbanks are contributing to contaminant concentrations in surface water, particularly in quiescent areas where surface water mixing and dilution is minimal. Loading estimates presented on **Figures 1.2-21** through **1.2-25** are consistent with this concept, indicating the mass flux of contaminants exiting the downstream end of the Site in surface water, either directly to the Columbia River or via Multnomah Channel, is greater than the flux entering the Site.

Contaminant concentrations in stormwater entering the Site are generally greater than concentrations associated with upstream surface water. On a mass loading basis, lateral contaminant loads associated with upland sources are comparable to upstream loads for certain contaminants.

Groundwater plume discharges to surface water have been observed in several areas where groundwater plumes are suspected or known to exist. Dissolved phase flux from surface sediments to the water column has been inferred from RI data.

Finally, tissue contaminant data and food web modeling indicate that persistent contaminants (particularly PCBs and dioxin/furans) in sediments and surface water bioaccumulate in aquatic species tissue.

The CSM integrates the information gathered to date and provides a coherent hypothesis of the contaminant fate and transport at the Site. **Figure 1.2-26** provides a simplified visual summary of this hypothesis, including the complete human and ecological exposure pathways.

1.2.5 Baseline Risk Assessment

This section presents a summary of the results of the baseline human health and ecological risk assessments (BHHRA and BERA). These assessments are presented in Appendix F and Appendix G of the RI report.

1.2.5.1 Baseline Human Health Risk Assessment

The overall process used for the BHHRA was based on the guidance provided in the *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final* (USEPA 1989). The BHHRA presents an analysis of the potential for effects associated with both current and potential future human exposures to contaminants at the Site. Potential exposure to contaminants found in environmental media and biota were evaluated for various occupational and recreational uses of the river, as well as recreational, subsistence, and traditional and ceremonial tribal consumption of fish caught within the Site. Infant consumption of human breast milk was also quantitatively evaluated because of the persistent and bioaccumulative nature of many of the contaminants found in sediment.

Consistent with EPA policy, the BHHRA evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. In addition, estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. **Figure 1.2-27** presents the conceptual site model (CSM) for the BHHRA and **Table 1.2-2** provides a list of contaminants potentially posing unacceptable risks for human health.

The major findings of the BHHRA are:

- Estimated cancer risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment and surface water. Risks and noncancer hazards from fish and shellfish consumption exceed EPA's acceptable cancer risk of 1×10^{-4} and target hazard index (HI) of 1 when evaluated on a harbor-wide basis, and when evaluated on the smaller spatial scale by river mile.

- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4×10^{-3} and 1×10^{-2} for recreational and subsistence fishers, respectively.

- Noncancer hazard indices for consumption of resident fish species are greater than 1 at all river miles. Based on a harbor-wide evaluation of noncancer risk, the estimated RME HI is 300 and 1,000 for recreational and subsistence fisher, respectively. The highest hazard estimates for recreational fishers are at RM 4, RM 7, RM 11, and in Swan Island Lagoon.

  The highest noncancer hazards are associated with nursing infants of mothers, who consume resident fish from the Site. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for breastfed infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME HI for tribal consumers of migratory and resident fish is 600 assuming fillet-only consumption, and 800 assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers, who consume fish, are 8,000 and 9,000 respectively, assuming maternal consumption of fillet or whole-body fish.

- PCBs are the primary contributor to risk from fish consumption. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall cancer risk and hazard indices. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The greatest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from the Site. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it is not clear to what degree contamination in the Site contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific adverse health effects, and the cancer estimates represent upper-bound values, and the EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.

1.2.5.2 Baseline Ecological Risk Assessment

The BERA evaluated the potential for adverse effects on plants, invertebrates, amphibians, fish, and wildlife from exposure to contaminants at the Site.

The overall process used for the BERA was based on the guidance provided in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final* (USEPA 1997c).

The following receptor groups and exposure pathways were evaluated in the BERA:

- **Benthic invertebrates—**Direct contact with sediment and surface water, ingestion of biota and sediment, and direct contact with shallow TZW
- **Fish—**Direct contact with surface water, direct contact with sediment (for benthic fish receptors), ingestion of biota, incidental ingestion of sediment, and direct contact with shallow TZW (for benthic fish receptors)
- **Birds and mammals—**Ingestion of biota and incidental ingestion of sediment
- **Amphibians and aquatic plants—**Direct contact with surface water and shallow TZW

The assessment endpoints for all ecological receptors are based on the protection and maintenance of their populations and the communities in which they live. Special status species (species that are protected by federal and/or state regulations or otherwise deemed culturally significant) are assessed at the organism-level for survival, growth, and reproduction. Juvenile Chinook salmon and Pacific lamprey were identified as special status species in the Site. For practical reasons, the organism-level measurement endpoints (survival, growth, and reproduction) were used for all receptors, requiring extrapolation to assess risks to populations and communities.

Figure 1.2-28 presents the CSM for the BERA and **Table 1.2-3** provides a list of contaminants of potential concern (COPCs) posing potentially unacceptable ecological risks within the Site. A list of contaminants identified as contaminants of ecological significance is provided in **Table 1.2-4**.

The following presents the primary conclusions of the BERA.

- Sixty six contaminants were determined to pose unacceptable risk to ecological receptors and are COCs. These 66 COCs included total PCBs, DDx, and total PAHs as individual COCs.
- Unacceptable risks to benthic invertebrates are clustered in 17 areas of concern.
- Contaminants in sediment and TZW that pose the highest risks tend to be clustered in areas that exhibit the greatest benthic invertebrate toxicity.
- PAH and DDx compounds are the COCs in sediment that are most commonly spatially associated with locations of unacceptable risk to the benthic community or populations.
- The combined toxicity of dioxins/furans and dioxin-like PCBs pose the greatest potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey.
- Of the 66 contaminants and contaminant classes posing unacceptable risks, 20 were determined to pose risks ecologically high enough to consider in the development of remedial actions. The criteria for this determination are: high unacceptable risks in more than one media; poses unacceptable risk over large areas; the spatial extent of unacceptable risk encompassing other contaminants that only pose risk in isolated areas, pose risks to multiple receptors, multiple lines of evidence demonstrating unacceptable risks, and exhibit the potential to bioaccumulate in the food web.

1.3 FS DATABASE DESCRIPTION

This section describes the FS database that contains the sediment data used in the alternatives development and evaluations in this FS. The source of the sediment data within the FS database is the Site Characterization and Risk Assessment (SCRA) database used for evaluations in the RI report (LWG as modified by USEPA 2016). However, the SCRA database did not use the same summing rules as were used in the baseline risk assessments. To allow for evaluations of risk reduction based on various alternatives presented in this report, it was necessary to ensure that the data were treated in a manner consistent with the baseline risk assessments. Data selection, evaluation, summation rules, and other rules and procedures for the FS database are described in Appendix A. The FS database only includes sediment data and does not contain pore water, surface water, TZW, or biota/tissue data; those data are retained in the SCRA database although they may be used for analysis in this FS.

For the RI and FS, a date collection of May 1, 1997, was used to define the initiation of the sediment dataset to follow the last major flood of the lower Willamette River in the winter of 1996. The SCRA database includes data collected through July 19, 2010. However, the following additional sediment data was added to the FS database:

- Additional updates to the SCRA database posted to the LWG's portal through February 4, 2011.

- Gasco engineering evaluation/cost analysis (EE/CA) data as provided by Anchor QEA in 2013 that meet the FS sediment database protocols described in Appendix A.

- Arkema EE/CA data as provided by Integral in May 2014 that meet the FS sediment database protocols described in Appendix A.

- DEQ's ECSI data for contaminated river banks identified in Section 1.2.3.5.

As noted in Section 1.2.2.3, the RM11E Group entered into an AOC to collect additional data (to include sediment, riverbank soil, pore water, and groundwater data) in support of preliminary remedial design activities. While the sediment data was not included within the FS database due to timing, all the data will be available in the Administrative Record for use during remedial design.

The SCRA database or the FS database may be used for some depictions or evaluations in this FS. Unless otherwise noted, the FS database was used for evaluations of sediment in this report.